

Program 9 **Quantitative Characterization of the Spatial Distribution of Particles in Materials: Application to Materials Processing**

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Objective

The objective of the present investigation is development of a broadly-applicable method for the quantitative analysis and description of the spatial distribution of second phase particles. This method should characterize the spatial distribution and its inhomogeneities in a manner which is of use to the materials scientist. As the method is intended to be available to a wide range of researchers in materials science, it has been designed to operate on a desktop computer. A second objective is application of the method for characterizing second phase particle distributions in a materials processing problem. The problem we have selected in consultation with the NASA technical monitor is understanding the effect of consolidation processing parameters on oxide particle distributions in a PM aluminum alloy.

A GEOMETRICAL DESCRIPTION OF MICROSTRUCTURE
WITH APPLICATION TO Al PM-PROCESSING

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Funded by NASA-Langley
(Light Aerospace Alloys and Structures Technology Program)

Inhomogeneities in the spatial distribution of second phase particles in engineering materials are known to affect certain mechanical properties. Progress in this area has been hampered by the lack of a convenient method for quantitative description of the spatial distribution of the second phase. The objective of this effort is the development of a widely accessible technique for the quantitative characterization and description of the spatial distribution of second-phase particles.

The Dirichlet tessellation technique (a geometrical method for dividing an area containing an array of points into a set of polygons uniquely associated with the individual particles) has been selected as the basis of an analysis technique, which has been implemented on a PC. The analysis characterizes properties of individual particles; such as local particle density, near-neighbor distances, etc.; and describes inhomogeneities such as clustering in the particle distribution.

This analysis technique is being applied to the production of Al sheet by PM-processing methods; vacuum hot-pressing, forging and rolling. The effect of varying hot working parameters (forging reduction, deformation temperature and total reduction) on the spatial distribution of aluminum oxide particles in consolidated sheet is being investigated. Changes in distributions of properties such as through-thickness near-neighbor distance correlate with hot-working reduction.

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**Funded by NASA Langley
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INTRODUCTION

- o The spatial distribution of second-phase particles in materials is known or predicted to affect properties such as toughness, modulus, and strength.**
- o Progress in this area has been hindered by the lack of a convenient method for quantitative characterization of the spatial distribution of second-phase particles.**
- o The objective of this effort is the development of a widely accessible technique for the quantitative characterization of the spatial distribution of second-phase particles.**
- o The Dirichlet tessellation technique was selected as the basis for the analysis.**

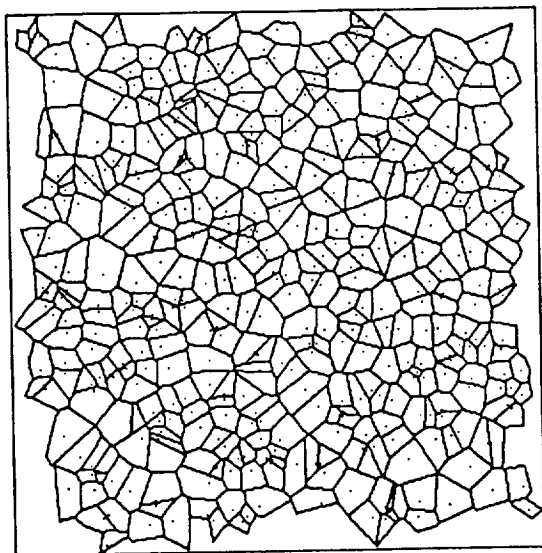
PREVIOUS WORK IN MATERIALS SCIENCE:

- o Previous work in this area has focused on the relationship between microstructure and properties.**
- o Embury found that clusters of second-phase particles were preferred sites for damage initiation and accumulation.**
- o Liu and coworkers studied effects of clustering of SiC particles in 7XXX-series MMC's; fracture experiments revealed that clustered sites were preferred sites for damage initiation.**

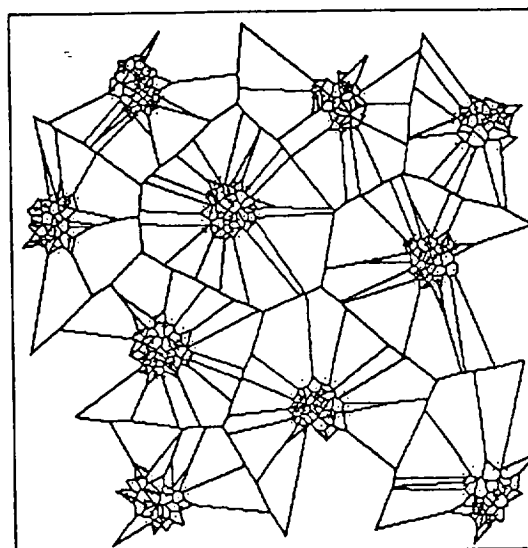
IMPLEMENTATION:

- o Implement analysis on a PC**

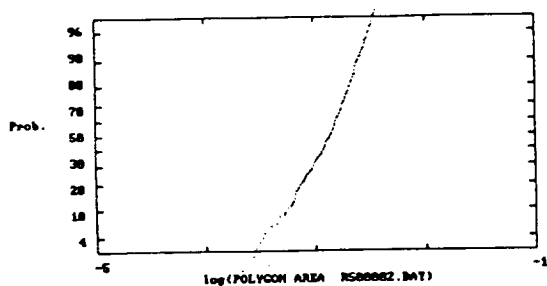
- > generate tessellations**
- > generate distribution of properties
(polygon areas, near-neighbor distances, etc.)**
- > verify operation with computer-generated
point arrays**



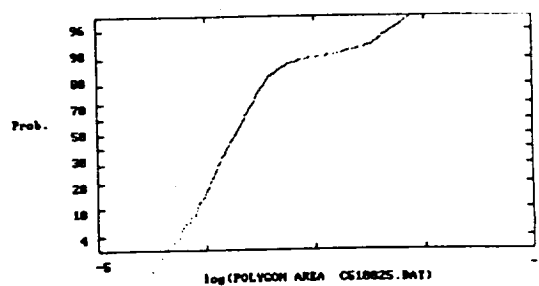
Tessellations: Random



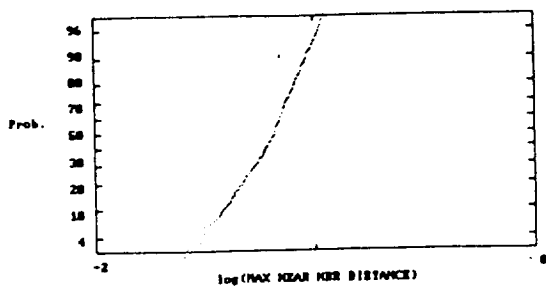
Clustered



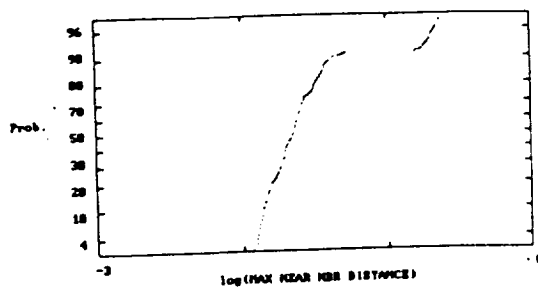
Polygon Area: Random



Clustered



Max.-Nbr. Distance: Random



Clustered

EXPERIMENTAL PROGRAM:

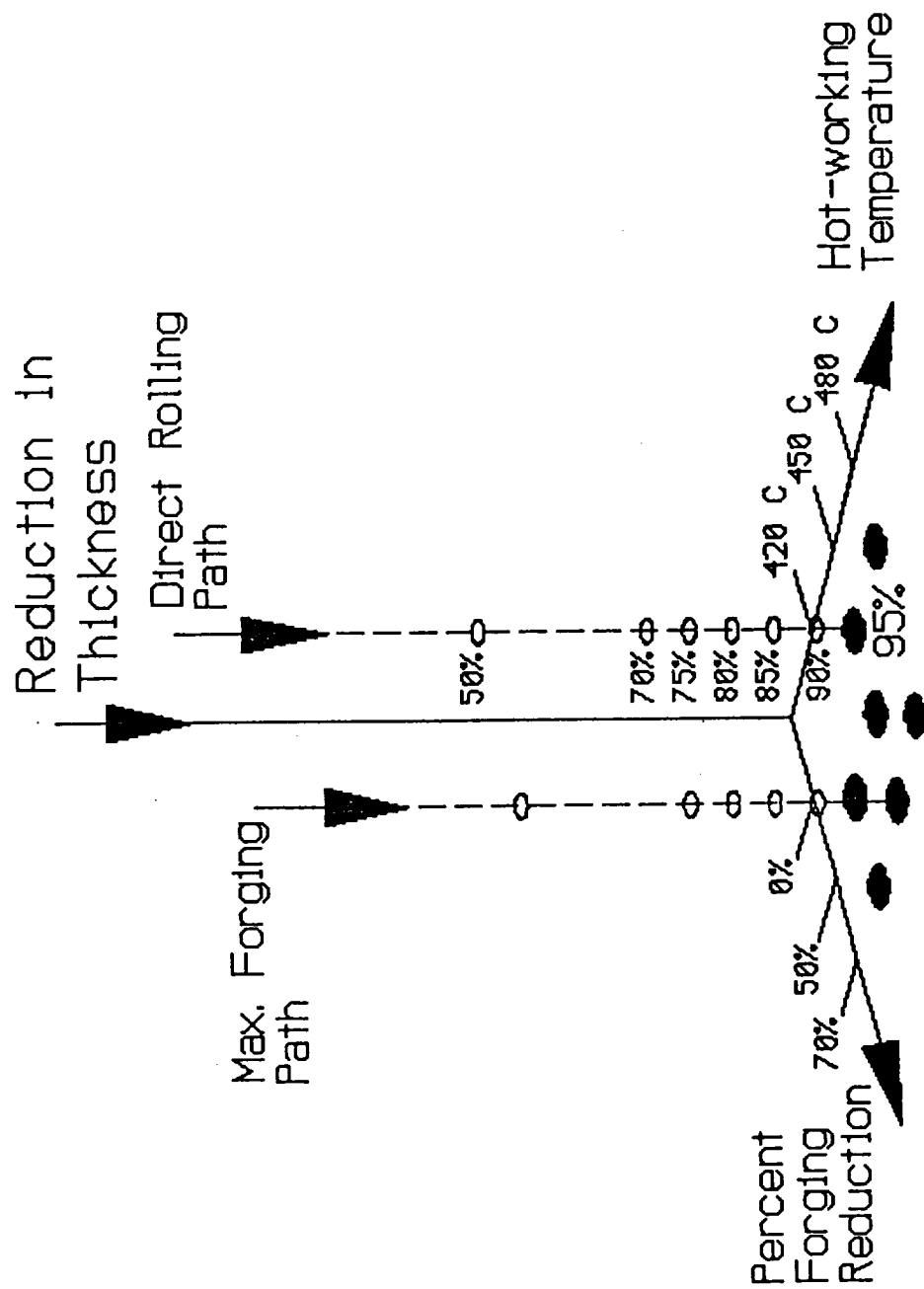
INVESTIGATE RELATIONSHIP BETWEEN PROCESSING PARAMETERS AND SPATIAL DISTRIBUTION OF SECOND-PHASE PARTICLES

o Material and process:

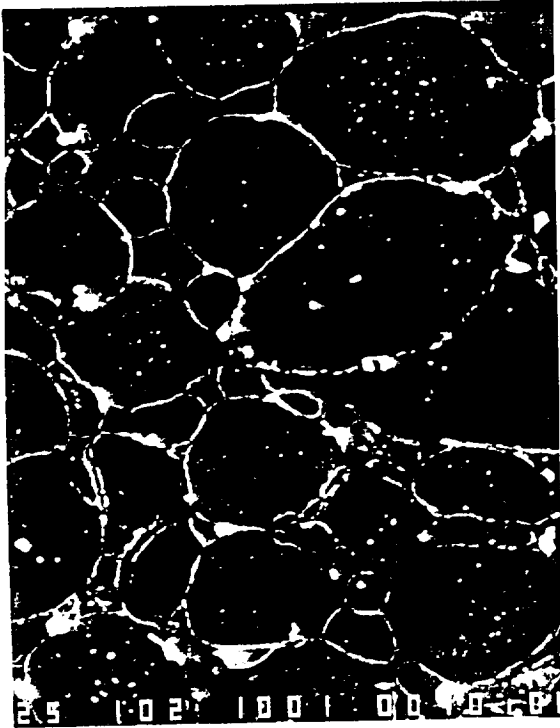
- > use RS Al-Mn-Si PM-Process sheet
as model material**
- > alloy system / process is under investigation
by NASA - Langley**
- > typical processing sequence:**
 - i) gas atomize powder ($\sim 27\mu\text{m}$)**
 - ii) cold compaction (to $\sim 70\%$ density)**
 - iii) vacuum hot press**
 - iv) forge and roll to $\sim 95\%$ reduction**
- > distribution of oxide as affected by hot-
working path (forging & rolling) is thought to
affect mechanical properties such as
toughness.**

Experimental variables:

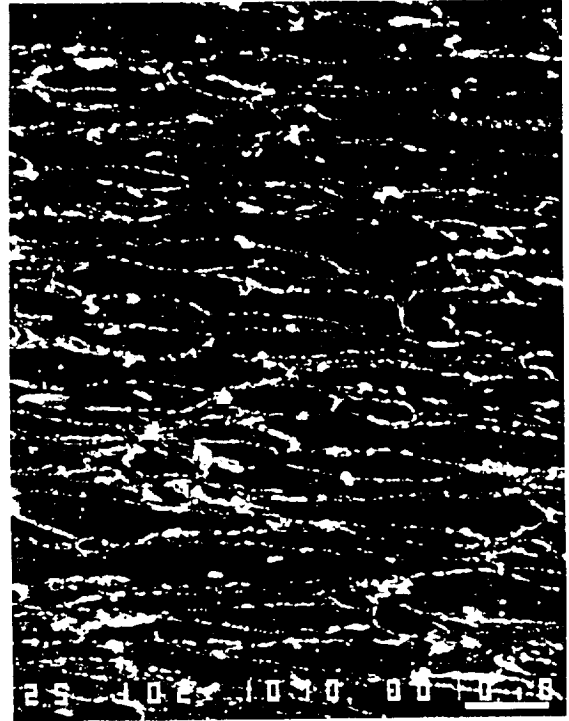
- o Duplicate processing procedures used at NASA with small samples**
 - > powder produced at NASA-Langley**
 - > consolidation and hot working performed at UVA**
- o Vary hot working parameters subsequent to consolidation.**
 - > temperature**
 - > forging reduction**
 - > total reduction**
- o Analyze oxide particle distributions**
- o Select processing conditions for production of larger samples at NASA for mechanical property measurements**



Experimental Conditions for Analysis

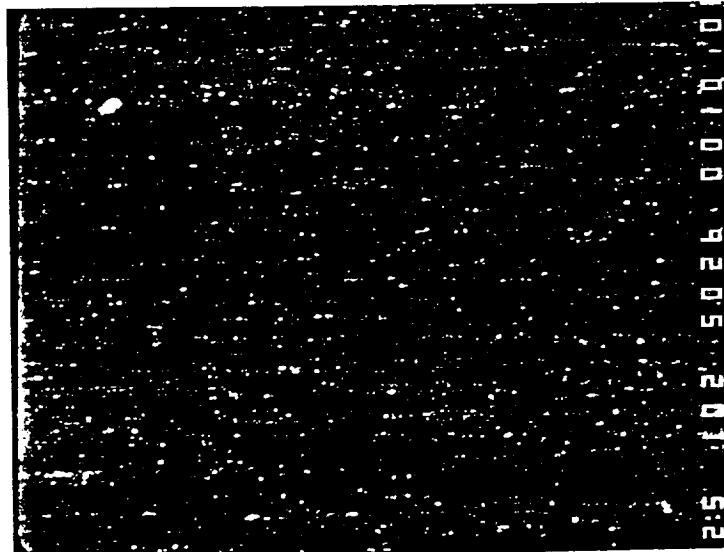


As Hot-Pressed

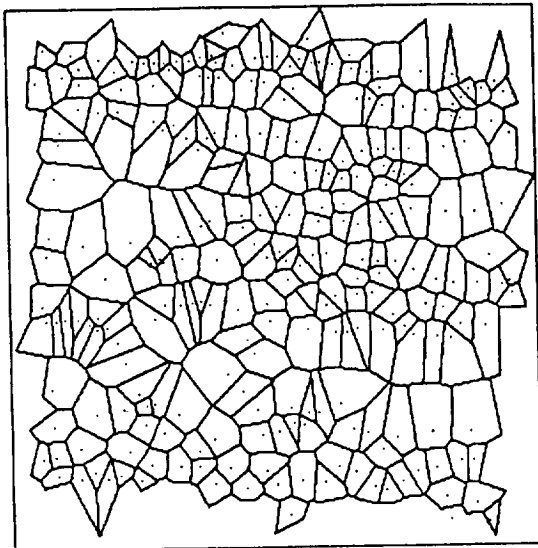


70% Forged

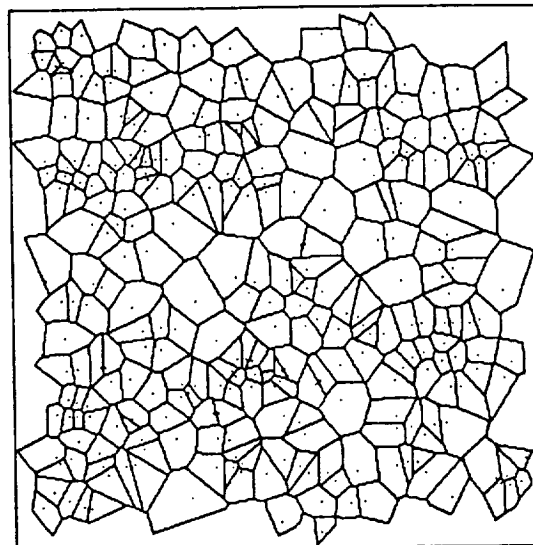
10 um



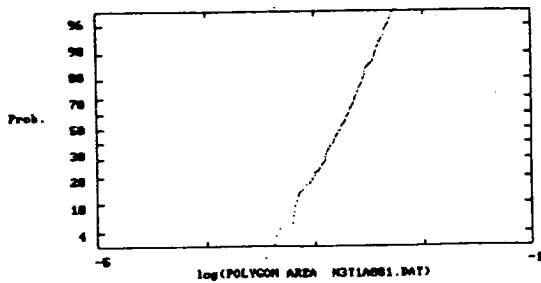
70% Forged + Rolled to 95%



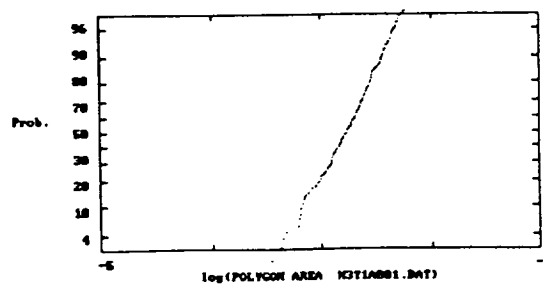
Tessellations: Forged 70%



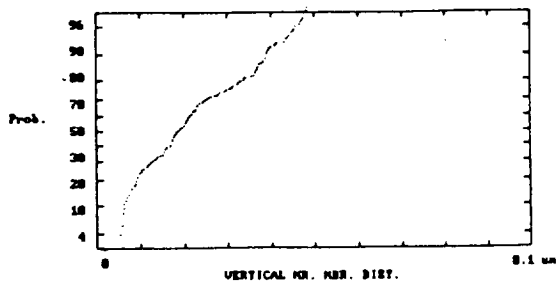
Forged 70%; Rolled to 95%



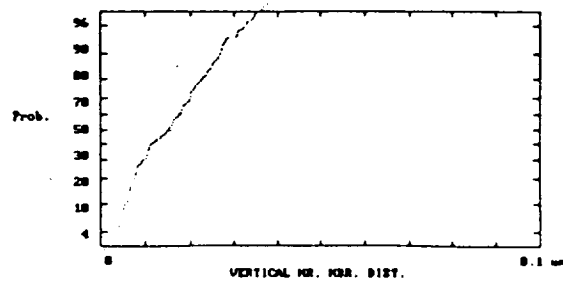
Polygon Area: Forged 70%



Forged 70%; Rolled to 95%



**Through-thickness
near-nbr. Distance: Forged 70%**



Forged 70%; Rolled to 95%

ORIGINAL PAGE IS
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EXPERIMENTAL RESULTS

o Evolution of oxide distribution during hot-working

- > gradual breakup and dispersion of oxide during deformation; prior particle boundaries still distinguishable at 70% forging reduction**
- > striking difference in oxide distribution between 70% forging reduction and subsequent rolling to 95% total reduction**
- > difficult to discern prior particle boundaries at 95% reduction**

o Results of analysis

- > distributions of polygon area show little change between 70% forging reduction and subsequent rolling to 95% reduction**
- > distributions of through-thickness nearest-neighbor distance show significant differences corresponding to reduction in thickness and elimination of prior particle boundaries**

CONCLUSIONS AND RECCOMENDATIONS:

- o Preliminary application of analysis to a model material has been made.**
- o Microstructural differences resulting from processing conditions can be quantitatively characterized by this technique.**
- o Future efforts will focus on analyzing the effects of hot-working on the spatial distribution of oxide particles for a wide range of hot-working procedures.**